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Methodology for Estimating Current and Future Burden of Osteoporosis in State Populations: Application to Florida in 2000 through 2025

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ABSTRACT

Objectives: The aging population is expected to increase the burden of osteoporosis on the US health-care system. We developed a methodology for estimating current and future costs of osteoporosis in state populations and applied it to Florida.

Methods: We used Florida hospital, population and mortality data, along with national data on outpatient and long-term care, to estimate the cost of osteoporotic fractures in the year 2000. For men and for "other" fractures in women, costs were based on the incidence of hospital admissions for fractures. For hip, spine, and wrist fractures in women, we integrated hospital and nonhospital fracture incidence in a Markov model of osteoporosis. Consecutive cohorts were run by race for each age, 50 to 99 years, to estimate the number and cost of incident fractures. Ongoing costs of prevalent fractures in women were estimated using postfracture health states for each individual age cohort. Total costs and fractures for the years 2001 through 2025 were projected by multiplying the base-year cost and fracture distribution by age-, sex-, and race-specific population growth rates.

Results: In Florida, 86,428 osteoporotic fractures were estimated to occur in the year 2000 at a cost of $1,238,445,114. By 2025, the estimated number of incident fractures would increase to 151,622, at a cost of $2,135,130,564.

Conclusions: This disease-modeling approach generates detailed information on the current and future cost burden of osteoporosis for an individual state population. Predictions based on this methodology may enable health-policy decisions that are tailored to local needs.

Keywords: burden, costs, fractures, health policy, Markov model, osteoporosis, race.

Introduction

The medical cost of osteoporosis and related fractures in the United States is estimated to range from $11.6 to $17.3 billion per year, adjusted to 2001 dollars [1–5]. Nevertheless, little is known about the cost of osteoporosis at the state level and the future impact of growth in the senior population. Local data may enhance planning and evaluation of interventions to manage the disease and control health-care expenditures. Nearly two-thirds of states have established osteoporosis education programs or task forces, and many state legislatures have mandated a needs assessment. Two states, Illinois and Pennsylvania, have published reports on hospital costs [6,7], and one journal article reports the burden of osteoporosis in California [8]. To help states plan current and future resource allocation over the next 25 years, we developed a methodology that can be applied to individual states and used for comparisons among states. The objectives were to evaluate costs by site of service, age, and race group, as well as to predict cost increases and the impact of future demographic shifts.

Our approach was designed to address several challenges to researchers evaluating the epidemiology and costs associated with osteoporotic fractures. First, the widespread underdiagnosis of osteoporosis can result in gross underestimation of costs. Total costs are driven primarily by hip fractures; however, even for hip fracture, a diagnosis of osteoporosis is rarely indicated in hospital records [9,10]. Another cause of underestimation is the failure to capture long-term costs of fractures. In addition, the limited availability of state data on outpatient and long-term care (LTC) costs is an

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obstacle to assessing overall medical cost at the state level. Finally, lack of a standard methodology has precluded valid comparisons among states.

To address underdiagnosis of osteoporosis in men and women, we focused on fracture costs and used published attribution rates, rather than osteoporosis diagnosis codes, to determine the proportion of total fractures that are attributable to osteoporosis. These attribution rates are based on work by Melton et al. [11] using a Delphi process with a panel of physicians highly experienced in the treatment and diagnosis of osteoporosis. For women, we supplemented this approach with a Markov model that simulates the natural history of osteoporosis. Our application included a new method of capturing the fracture history of a specific population to determine costs of prevalent (pre-existing) as well as incident (new) fractures. We applied this methodology to the state of Florida, which has the nation's second largest senior population. The National Osteoporosis Foundation estimates that Florida has 3.01 million women and men with osteoporosis or osteopenia (low bone mineral density) in 2002, and prevalence will increase by 25% to 3.77 million in 2010 and by 56% to 4.72 million in 2020 [12].

Methods

We developed a methodology to estimate the current and future burden of osteoporosis for a state population aged 50 years and older. Whenever possible, we used state-specific data, including age- and sex-specific population, mortality, and all-payer hospital discharge data. For both sexes and all fracture types, costs included Florida hospital costs and estimates of posthospital care based on Florida hospital discharge data and published national statistics. In addition, for hip, spine, and wrist fractures in women, the availability of overall fracture incidence data enabled use of a Markov state-transition model of osteoporosis to better estimate costs after both incident and prevalent fractures. Although our reliance on events linked to hospitalization underestimates the cost of fractures in men and other (nonhip, nonspine, nonwrist) fractures in women, this approach provides a total estimate of disease burden that is valuable to state policymakers [6,7]. Only medical costs and direct nonmedical costs, for example, transportation for long-term disability, were included in the analysis because data were unavailable to accurately assess indirect costs such as caregiver time, and lost work time is generally a minor cost for a senior population [8].

Description of the Model

The Markov state-transition model of osteoporosis simulates the natural history of osteoporosis in women beginning at the age of 50 years and continuing through the age of 99 years. In the model, a cohort is followed as it transitions from a healthy state to a healthy, fracture, or dead state, using 1-year cycles. Long-term consequences after a hip or spine fracture are captured using postfracture health states. Outcomes after hip fracture are assumed to dominate those associated with other types of fracture. Individuals are limited to two hip fractures per lifetime. This model was developed and validated using age-specific hip, spine, and wrist fracture data and age-specific mortality data for women in the United States, Canada, and Sweden [13].

Epidemiology Inputs

The epidemiology inputs included population size, mortality rates, and fracture incidence rates. We used population data for the following race/ethnic groups, hereafter referred to as "race": non-Hispanic white, non-Hispanic black, Hispanic white, Hispanic black, and other. Age-specific population data for men and women aged 50 through 99 years in Florida from 2000 through 2025 were obtained from a census publication [14], which accounted for all forms of in-migration, out-migration, and mortality. General population mortality rates for men and women aged 50 through 99 years in Florida were obtained from the Centers for Disease Control, National Center for Health Statistics [15]. For the Markov model, age-specific excess mortality rates associated with hip fractures in women were obtained from a study conducted in the United Kingdom [16] because age-specific rates were not available for individual states or for the entire United States.

Florida hospital and population data were used to calculate incidence rates for hip and other fractures in men and women aged 50 through 99 years, as well as spine and wrist fractures in men [17]. For hip fractures, hospital incidence represents overall incidence. For spine [18] and wrist [19] fractures in women, overall incidence includes hospital and nonhospital incidence rates that were obtained from an epidemiologic study conducted in Rochester, Minnesota. The spine fracture rates indicate total fractures that would be detected by radiograph. Because the Rochester population may not be representative of the racial mix in Florida, we evaluated alternative incidence rates by race in the sensitivity analysis. Table 1 summarizes fracture

Table 1 Annual fracture incidence rates per 10,000 Florida women, by age and race group and fracture type

		Age (years)							
		50–64		65–74		75–84		≥85	
Race	Fracture	Unadj.*	Adj.†	Unadj.*	Adj.†	Unadj.*	Adj.†	Unadj.*	Adj.†
White‡	Hip§	8.7	7.0	36.5	32.8	131.3	118.2	391.2	371.6
	Spine‖	59.3	47.4	166.2	149.6	309.2	278.2	447.0	424.7
	Wrist¶	48.7	34.1	60.6	42.4	53.3	37.3	68.8	55.1
Black‡	Hip§	3.8	2.5	17.5	14.0	55.5	44.4	164.9	156.6
	Spine‖	57.9	37.7	161.2	129.0	306.2	245.0	447.0	402.3
	Wrist¶	48.0	26.4	59.6	35.7	53.2	31.9	68.8	48.2
Hispanic#	Hip§	4.9	3.8	25.3	22.6	115.1	103.0	330.6	314.1
	Spine‖	59.2	46.9	162.4	145.4	307.9	276.1	447.0	424.0
	Wrist¶	48.7	33.7	59.8	41.6	53.2	37.1	68.8	54.9
Other‡	Hip§	16.8	12.6	45.0	38.3	369.5	314.1	1268.3	1204.8
	Spine‖	56.3	42.2	160.4	136.4	303.9	258.3	447.0	424.7
	Wrist¶	47.0	28.2	59.4	41.6	53.0	37.1	68.8	48.2

*Incidence rates were weighted by population within age group and race. Rates are reported here by age group, whereas the analysis employed incidence rates by individual age.
†Incidence rates adjusted using age/race-specific attribution probabilities for each fracture type [11].
‡Excludes any race with Hispanic ethnicity.
§Incidence rates calculated from 1998 Florida Hospital Inpatient Data File and population from US Census Bureau.
‖Melton et al. [18].
¶Melton et al. [19].
#Includes any race with Hispanic ethnicity.

incidence rates for women by age group and race, before and after downward adjustment using Melton's osteoporosis attribution rates [11]. Note that incidence rates by individual age were used in the analysis. The attribution rates were applied as follows: white rates for non-Hispanic whites and white Hispanics, black rates for non-Hispanic blacks and black Hispanics, and other rates for other race groups.

Cost Inputs

We used the 1998 Florida AHCA Inpatient Data File in estimating inpatient, outpatient, and LTC costs for men and women. We selected cases with a primary admission diagnosis of fracture on the discharge record (ICD-9 codes for closed hip fracture [733.14, 808.0x, 808.2x, 808.4x, 808.8x, 820.0x, 820.2x, 820.8x]; closed spine fracture without spinal cord injury [733.13, 805.0x, 805.2x, 805.4x, 805.8x], wrist fracture [733.12, 813.xx], or other fracture [733.1x and 800.xx–829.xx, excluding those for hip, spine, wrist]). For hip fractures, we also incorporated published estimates of the costs of acute inpatient physician services [20], hospital readmissions [20,21], and rehabilitation and short-stay hospitalization [20,21]. For spine fractures, costs for inpatient physician services were estimated using the physician service utilization profile from the literature [20] and the 2000 Medicare Fee Schedule.

In the Markov model, the mean inpatient costs for wrist fractures in women were multiplied by 0.10 [3] to adjust overall fracture incidence rates for the low proportion of wrist-fracture patients who receive inpatient care. For spine fractures, a factor of 0.425 was applied to noninpatient costs [22,23] to reflect the proportion of radiographically detectable spine fractures that receive medical care. A larger reduction factor of 0.123 ($= 0.29 \times 0.425$) was used for inpatient costs, based on an estimate that 29% of clinical spine fractures are admitted to inpatient hospitals [23,24]. For men, downward adjustments to spine and wrist fracture costs were unnecessary because these costs were based on inpatient hospital admissions.

Outpatient costs for hip and spine fractures included posthospitalization physician visits [21] and medical and nonmedical home care [21]. For wrist and other fractures, outpatient costs were estimated by taking the national proportion of outpatient to inpatient costs [1] and multiplying by the corresponding mean Florida inpatient fracture costs.

The expected costs of LTC for hip fractures were derived by multiplying the probability of using LTC, estimated from Florida hospital discharge data, weighted by length of stay for partial and full-year stays [20,21], by the per diem cost of $124 [25,26]. National estimates for disability and dependency care costs [21] were summed together with LTC facility costs to create total expected LTC costs during the first year after a hip fracture. The ongoing costs for LTC and disability/dependency care after the first year were obtained from the literature [21]. For nonhip fractures, a national proportion of LTC to inpatient care costs [1] by fracture type was

Table 2 Expected unit costs ($) for fractures, by sex and age

	Age (years)							
	Women				Men			
Cost category	50–64	65–74	75–84	≥85	50–64	65–74	75–84	≥85
Hip fractures								
Inpatient*	25,038	20,505	21,663	21,400	30,087	23,805	23,401	24,139
Outpatient†	2,408	2,122	2,142	2,137	2,494	2,220	2,213	2,225
LTC, first year	8,992	13,387	15,501	15,526	7,772	10,559	13,630	13,715
LTC, years >1	4,323	4,323	4,323	4,323	—	—	—	—
Spine fractures‡								
Inpatient	1,452	1,486	1,277	1,450	12,086	7,637	7,141	6,138
Outpatient	296	296	294	296	368	328	324	314
LTC, first year	115	118	101	115	1,048	660	617	527
LTC, years >1	115	118	101	115	—	—	—	—
Wrist fractures§								
Acute inpatient hospital	905	1,061	1,053	1,430	12,806	10,235	8,340	10,377
Outpatient	460	539	535	727	840	671	547	680
LTC, first year	203	238	236	320	2,869	2,293	1,868	2,325
Other fractures								
Acute inpatient hospital	16,438	16,466	14,778	13,360	17,662	18,344	14,638	14,843
Outpatient	2,823	2,828	2,538	2,295	3,304	3,149	2,514	2,549
LTC, first year	6,542	6,553	5,881	5,317	7,029	7,296	5,825	5,907

*Includes inpatient facility, inpatient physician, readmission, and rehabilitation/short-stay costs for women.
†Includes outpatient visits, home health care, and nonmedical home care.
‡For women, inpatient costs multiplied by 12.3% and all other costs multiplied by 42.5% before use in the model. Costs for men were not factored down, because radiographic incidence rates were not used for men.
§For women, inpatient costs multiplied by 10% (to reflect the proportion of all wrist fractures admitted to an inpatient hospital) before use in model, which employed overall incidence (hospital and non-hospital) rates. Costs for men were not factored down, because overall incidence rates were not used for men.
Abbreviation: LTC, long-term care. Includes LTC facility and disability/dependency.

multiplied by the respective mean fracture cost in Florida.

Table 2 shows expected unit costs for each fracture type by age and sex. A detailed description for hip fracture is provided in Appendix 1. All unit costs were converted into year 2000 terms using the Medical Care Component of the urban Consumer Price Index [27].

Calculation of Base-Year Costs and 25-Year Projections

In the Base Year 2000, for men, the total cost of fractures was calculated based on the incidence of hospital admissions for all fracture types. For women, total cost was based on hospital incidents for hip and other fractures and based on overall fracture incidence rates, hospital and nonhospital, for wrist and spine fractures. Future costs and fractures for the years 2001 through 2025 were projected by multiplying the base-year cost and fracture distribution by the respective age-, sex-, and race-specific population growth rates. All projections were in real terms, reflected the cost structure in 2000, and assumed that the true rate of inflation was equal to the real rate of interest.

For women, the base year included costs of prevalent hip and spine fractures, which were estimated by an iterative process. For each race group, white, black, Hispanic white, Hispanic black, and other, we ran the Markov model 50 times, once for each age cohort 50 through 99 years of age. Incident fracture costs were obtained from the first year of follow-up, and disease history was simulated by tracking younger cohorts, up to a maximum of 25. For example, for the cohort of 65-year-old persons, the younger cohorts of 50- to 64-year-old persons were "aged up" to 65 years, and posthip and post-spine fracture costs were determined for each of these cohorts at 65 years of age. Costs from previous fractures, which reflect age-specific mortality and fracture incidence rates, were averaged over the number of contributing cohorts.

Results

Fractures accounted for 43,520 admissions to Florida hospitals in 1998. After adjustment for osteoporosis attribution probabilities and elimination of high-cost outliers, osteoporotic fractures accounted for 32,255 admissions to Florida hospitals in 1998 (Table 3). Osteoporotic hip fractures resulted in approximately 68% of admissions, spine fractures in 12%, wrist fractures in 3%, and other fractures in 17%. These fractures accounted for 172,814 hospital bed days and nearly $574 million in hospital charges. Patients with hip fracture had a mean length of stay of 5.9 days, and 61% were discharged to a LTC facility. Patients with spine frac-

Table 3 Mean and total gross charges, hospital days, and percentage discharged to LTC for osteoporotic fractures in men and women aged 50 years and older, admitted to Florida hospitals during 1998*

Fracture type	Number of hospital admissions†	Hospital costs ($)			Length of stay (days)			Discharges to LTC facility (%)
		Mean	SD	Total	Mean	SD	Total	
Hip	21,827	20,614	14,699	447,782,267	5.9	4.8	127,512	61
Spine	3,991	8,992	5,806	35,707,626	4.7	2.9	18,743	42
Wrist	1,044	12,136	6,121	12,522,002	2.9	1.7	3,024	24
Other	5,394	14,707	10,000	77,952,650	4.3	3.3	23,536	38
Total	32,255	17,383	23,677	573,964,545	5.2	5.7	172,814	54

*Florida Hospital Inpatient Data File, State of Florida Agency for Health Care Administration, 1998.
†Total admissions after applying osteoporosis attribution probabilities by age, sex, and race. An additional 1194 high-cost cases were excluded (21 hip, 357 spine, 101 wrist, 715 other).
Abbreviation: LTC, long-term care.

ture had a mean length of stay of 4.7 days, and 42% were discharged to a LTC facility.

The projected total medical cost of osteoporosis in 2000 was nearly $1.24 billion (Table 4). People aged 50 to 64 years represented approximately 8% of total medical costs, those aged 65 to 74 years accounted for 16%, those aged 75 to 84 years comprised 36%, and those aged 85 years and older accounted for 39%. Inpatient costs made up the majority of the total costs ($689.2 million [56%]), followed by LTC ($452.8 million [37%]) and outpatient care ($96.4 million [8%]). Across age groups, the proportion of costs as a result of outpatient care was nearly equivalent (8%), whereas LTC appeared to represent a higher share of total costs among older patients. Specifically, LTC comprised 24% of costs in the 50- to 64-year age group, 32% in the 65- to 74-year age group, 37% in the 75- to 84-year age group, and 41% in the 85-year-and-older age group.

Total annual costs were projected to increase from the base year 2000 level of $1.24 billion to $1.54 billion (24%) in 2010 and $2.14 billion (72%) in 2025 (Table 5; Fig. 1). The total number of osteoporotic fractures was projected to increase from 86,428 in 2000, to 107,026 (24%) in 2010, and to 151,622 (75%) in 2025. Hip fracture events were projected to increase by almost 72% by 2025, and spine fractures by 77%. Although hip fractures comprised the majority of costs, spine fractures accounted for about 51% of all osteoporotic fractures. Spine fractures resulted in only 8% of total costs because most of these cases do not come to medical attention, and most of those that do receive medical care are treated in lower cost outpatient settings.

Women represented more than $927 million (75%) of the total annual medical care costs in 2000 and were projected to reach $1.6 billion in 2025. The costs for men were about $311 million in the base year and were predicted to be nearly $529 million by 2025. By race, whites had over 73,000 fractures for over $1 billion (87%) in 2000. By 2025, total fractures and costs for white persons increase by about 50%, but total share of the projected $2.1 billion cost falls to 74%. The "other" race group has the lowest share of the total cost (2%) in 2000 but shows the largest growth rate. Hispanic and black persons account for 8.1 and 2.8% of the base year costs, increasing to 16.2 and 3.9%, respectively, by 2025. For Hispanic persons in the age groups 65 years and older, hip fracture incidence rates are 69% to 88% of the rates in white persons (Table 1). Thus, both population growth and fracture incidence contribute to the predicted growth in total fractures and costs for His-

Table 4 Distribution of costs of osteoporosis in Florida for 2000, by site of care and age group

Age (years)	Cost ($) by site of medical care (% of total for each age group)			Total
	Inpatient*	Outpatient†	LTC	
50–64	67,049,787 (67)	9,136,084 (9)	24,087,081 (24)	100,272,952 (100)
65–74	120,494,862 (60)	16,294,959 (8)	64,611,694 (32)	201,401,516 (100)
75–84	248,303,716 (55)	34,636,092 (8)	166,840,852 (37)	449,780,660 (100)
≥85	253,404,844 (52)	36,339,196 (7)	197,245,947 (41)	486,989,986 (100)
Total	689,253,209 (56)	96,406,332 (8)	452,785,573 (37)	1,238,445,114 (100)

*Inpatient includes acute inpatient facility and physician costs, readmissions to acute care hospitals, and costs for rehabilitation/short-stay hospitals.
†Outpatient includes medical and nonmedical home care costs, posthospital and outpatient physician visits, and other outpatient care.
Abbreviation: LTC, long-term care, which includes LTC facility costs and disability/dependency.

Table 5 Projected costs related to osteoporosis in Florida by fracture type, sex, and race

	Cost ($) and number of fractures [in brackets] (% change from base year)			
	Base year 2000	2005	2010	2025
Fracture type				
Hip*	949,062,534	1,068,022,769 (12.5)	1,179,295,694 (24.3)	1,631,693,613 (71.9)
	[24,004]	[27,029] (12.6)	[29,842] (24.3)	[41,346] (72.2)
Spine*	100,202,676	110,769,217 (10.5)	122,834,236 (22.6)	176,939,783 (76.6)
	[44,382]	[48,914] (10.2)	[54,045] (21.8)	[78,332] (76.5)
Wrist*	16,913,891	19,257,994 (13.9)	22,179,745 (31.1)	30,348,606 (79.4)
	[11,086]	[12,584] (13.5)	[14,529] (31.1)	[20,056] (80.9)
Other*	172,266,013	191,755,265 (11.3)	213,115,445 (23.7)	296,148,562 (71.9)
	[6,957]	[7,750] (11.4)	[8,609] (23.7)	[11,889] (70.9)
Total*	1,238,445,114	1,389,805,245 (12.2)	1,537,425,120 (24.1)	2,135,130,564 (72.4)
	[86,428]	[96,276] (11.4)	[107,026] (23.8)	[151,622] (75.4)
Sex and race				
Women†	927,086,951	1,045,311,217 (12.8)	1,159,506,256 (25.1)	1,606,233,515 (73.3)
	[77,644]	[86,558] (11.5)	[96,361] (24.1)	[136,735] (76.1)
Men†	311,358,163	344,494,028 (10.6)	377,918,865 (21.4)	528,897,049 (69.9)
	[8,784]	[9,718] (10.6)	[10,664] (21.4)	[14,887] (69.5)
White‡	1,082,874,008	1,185,093,818 (9.4)	1,270,473,814 (17.3)	1,587,007,133 (46.6)
	[73,005]	[79,112] (8.4)	[85,183] (16.7)	[109,487] (50.0)
Black‡	34,618,806	41,359,370] (19.5)	49,497,401 (43.0)	82,870,548 (139.4)
	[3,972]	[4,781] (20.4)	[5,777] (45.5)	[9,666] (143.4)
Hispanic‡	99,935,232	130,007,752 (30.1)	167,738,409 (67.8)	346,030,356 (246.3)
	[8,350]	[10,693] (28.1)	[13,625] (63.2)	[26,973] (223.0)
Other‡	21,017,068	33,344,305 (58.7)	49,715,497 (136.5)	119,222,526 (467.3)
	[1,102]	[1,690] (53.4)	[2,440] (121.4)	[5,496] (398.8)

*All races, both sexes.
†All races.
‡Both sexes.

panic persons. Growth is most substantial after 2010, and by 2025 costs and fractures in Hispanic persons are predicted to increase 2.5-fold.

Sensitivity Analysis

We assessed the impact on the base-case results from changes in unit costs, the true rate of inflation, and race-specific fracture incidence rates. For inpatient charges, the cost was reduced by 30% for the low-cost scenario and increased by 10% for the high-cost scenario. All other costs were reduced by 25% for the low-cost scenario and increased by 25% for the high-cost scenario, as is commonly done when measures of statistical variation are unavailable. The ranges in base-year total costs were $1.08 billion under the low-cost scenario to $1.39 billion under the high-cost scenario (Table 6). The low-to-high ranges in total cost were approximately $1.34 billion to $1.74 billion in 2010 and $1.87 billion to $2.41 billion in 2025. When 1% was used as the true rate of inflation and 3% was used as the real interest rate, costs were estimated to be $1.26 billion in 2010 and over $1.30 billion in 2025. When 5% was used as the true rate of inflation and 3% was used as the real interest rate, costs were estimated to be $1.86 billion in 2010 and $3.45 billion in 2025. Finally, we applied alternative incidence rates for spine and wrist fractures, according to race. Hip and other fracture incidence rates were not changed from the base case because these fracture incidence rates already are race-specific based on the estimates from Florida hospital data. An adjustment factor of 0.33 was applied to wrist fracture incidence rates for all nonwhite races [28,29], and for spine fractures multipliers of 0.25, 0.55, and 0.33 were used for black, Hispanic, and other race groups, respectively [30–32]. In this scenario, costs for 2000 were slightly lower versus the base case, $1.230 billion versus $1.238 billion, as was total cost growth over time. In summary, the base-case results were generally robust when subjected to alternative values for key parameters. As expected,

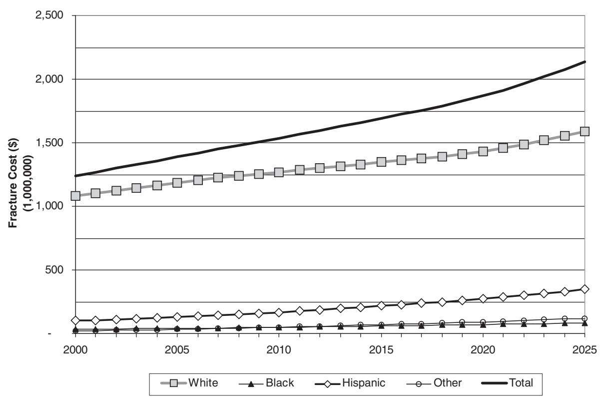

Figure 1 Osteoporosis costs in Florida by race, 2000 through 2025.

Table 6 Sensitivity analysis of total costs of osteoporosis in Florida for 2000, 2005, 2010, and 2025, using low and high unit costs, low and high true rate of inflation, and race-specific fracture incidence rates

	Year			
Scenario	2000	2005	2010	2025
Base case*	1,238,445,114	1,389,805,245	1,537,425,120	2,135,130,564
Low-cost case*	1,081,131,525	1,212,491,014	1,341,586,697	1,869,276,948
High-cost case*	1,397,018,821	1,569,034,933	1,736,127,215	2,409,776,674
Base case				
i = 1%; r = 3%	1,238,445,114	1,260,012,030	1,263,675,203	1,307,760,346
i = 5%; r = 3%	1,238,445,114	1,530,080,633	1,863,437,008	3,453,236,292
Race-specific fracture incidence rates†	1,230,978,859	1,380,349,030	1,525,505,703	2,112,586,120

*Assumes both true rate of inflation, i, and real rate of interest, r, equal 3%.
†Base-case fracture incidence rates multiplied by 0.25, 0.55, and 0.33 for Black, Hispanic, and other, respectively, for spine fracture; and 0.33 for wrist fracture (all nonwhite races).

the long-term projections were most sensitive to changes in the true rate of inflation.

Discussion

We developed a general methodology to estimate the number of osteoporotic fractures and associated medical costs for a given state population. A Markov model of osteoporosis was used to create cost estimates for hip, spine, and wrist fractures in women. We combined these results with costs for other fractures in women and all fractures in men based on inpatient hospital admissions to yield total population costs for 2000 through 2025. The model's flexible input design enabled us to take advantage of data available in an individual state and supplement with national data as needed. This methodology contrasts with a "top-down" accounting approach where the cost burden for an individual state is derived from national figures, failing to account for variations in population distribution by age, sex, and race, and medical practice patterns among states.

Our methodology has the advantage of applicability across states, providing a standardized study design that facilitates interstate comparisons. In contrast, three earlier studies of state inpatient databases each took a different approach to identifying osteoporosis-related admissions and costs. The Illinois Department of Public Health selected patients with a principal diagnosis of osteoporosis or pertinent fracture but included wrist or spine fractures only if there was a secondary diagnosis of osteoporosis [6]. The Pennsylvania Health Care Cost Containment Council (PHC4) studied only patients with a diagnosis of osteoporosis [7]. The California study included both patients with a diagnosis of osteoporosis and those with fractures attributable to osteoporosis [8]. The ICD-9 codes used to select fracture cases also differed across these studies. As a result, the Pennsylvania study [7] found hip fractures to comprise only 21% of osteoporosis-related hospital admissions compared with 78% in Illinois [6], 48% in California [8], and 68% in our analysis of Florida data. Conversely, the Illinois study [6] found wrist and spine fractures to comprise less than 2% of osteoporosis-related hospitalizations compared to more than 26% in Pennsylvania [7], 11% in California [8], and 16% in Florida. Although demographics and health-care practices may contribute to interstate variation in osteoporosis-related hospital admissions, methodologic differences probably account for the wide range in these results.

We found that hospitalization contributed more than half of total medical costs in Florida in 2000, with hip fractures driving those expenditures. The distribution of cost by site of service was 56% for inpatient, 8% for outpatient, and 37% for LTC. These proportions are similar to national estimates by Ray et al. [1] of 62%, 9%, and 28%, using 1992 hospital data and 1985 LTC facility data. The lower inpatient share and higher LTC share in Florida may reflect changes in practice patterns over the past decade. Hospitals have had strong incentives to minimize hospital days and discharge patients to skilled LTC facilities or other types of follow-up care. Shen et al. [6] reported a steady decrease in average length of stay for osteoporosis-related hospitalizations in Illinois from 1992 (10.1 days) through 1995 (7.4 days), along with an increase in discharges to LTC facilities. In California, Max et al. [8] found that LTC facilities represented the majority (59%) of total costs in 1998. Inpatient and outpatient care, including home health, each contributed approximately 20% of total costs. These relatively high LTC and outpatient costs might be explained in part by California's managed care environment. However, Max et al. [8] derived these costs from national data sources such as the 1996

Medical Expenditure Panel Survey and the 1997 National Nursing Home Survey, rather than California data. Further research is needed to evaluate differences in databases and their implications for osteoporosis costs.

This analysis may underestimate total costs and fractures as a result of several limitations and conservative assumptions. First, only costs of medical care and direct nonmedical care were included in our analysis. Costs of unpaid caregiver time, for example, were not estimated. Second, the analysis excluded individuals less than 50 years of age, although glucocorticoid-induced osteoporosis often occurs in younger age groups. Third, inpatient costs were based only on hospital cases with fractures as a primary diagnosis. Recent research on comorbid costs of spine fractures, as secondary diagnoses, suggests that hospital stays are extended by 2 to 3 days [33,34]. In the study by Max et al. [8], more than 22% of total hospital costs were derived from excess costs of osteoporosis as a secondary diagnosis. Fourth, our analysis did not fully capture costs of osteoporosis that were not driven by fractures, such as LTC facility admissions owing to frailty, kyphosis, or pressure on other organs. Fifth, the use of constant relative resource prices over time represents an extremely conservative assumption because medical care costs have been growing faster than the economy-wide rate of inflation for several decades. On the other hand, in our base case analysis, we applied a cost-to-charge-ratio (CCR) of 0.8, for example, a 20% discount, to inpatient hospital charges. The use of a lower CCR would lead to lower unit costs of fractures. We attempted to address the uncertainty around all unit cost inputs through our sensitivity analyses. Furthermore, our methodology can easily accommodate newer or more precise unit cost estimates as they become available.

An important limitation is the method of estimating other fractures and all fractures in men. The Markov model was not used for these fracture events because we lacked overall incidence data. Our cost data represent only current year costs for incident fracture events that were related to an inpatient hospital episode. Most spine and wrist fractures do not result in a hospital admission; but many do require medical attention such as physician visits, medical supplies, and drugs. Thus, the total number and costs of these fractures in men are clearly underestimated. Another limitation of this analysis is the combined use of Florida and national data and the accompanying assumptions for estimating the costs per fracture type. Our description of hospital fracture admissions and discharges to LTC begins to elucidate how the cost structure and osteoporosis practice patterns in Florida differ from the rest of the nation.

Conclusions

On balance, this analysis provides conservative estimates of the total cost of osteoporosis in Florida. Our base case probably forms a lower bound on total costs. Nonetheless, the costs are staggering and are estimated to grow from $1.24 billion in 2000 to $2.14 billion in 2025. Costs of osteoporotic fractures in Hispanic persons are projected to increase 2.5-fold. The richness of information generated by our methodology should assist policy makers in planning for future health service needs, such as increasing demand for LTC. In addition, our findings may help target interventions to rein in burgeoning osteoporosis costs by increasing diagnosis and treatment of osteoporosis in older Floridians at high risk of fracture. For example, culturally appropriate interventions may be valuable in preventing a dramatic increase in osteoporotic fractures in Hispanic persons. This methodology can also be used for cost derivation in other states and provides a standardized means for making comparisons among states.

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References

1 Ray NF, Chan JK, Thamer M, et al. Medical expenditures for the treatment of osteoporotic fractures in the United States in 1995: report from the National Osteoporosis Foundation. J Bone Miner Res 1997;12:24–35.
2 Hoerger T, Downs K, Lakshmanan M, et al. Healthcare use among US women aged 45 and older: total costs and costs for selected postmenopausal health risks. J Womens Health Gend Based Med 1999;8:1077–89.
3 Chrischilles E, Shireman T, Wallace R. Costs and health effects of osteoporotic fractures. Bone 1994;15:377–86.
4 Phillips S, Fox N, Jacobs J, et al. The direct medical costs of osteoporosis for American women aged 45 and older, 1986. Bone 1988;9:271–9.
5 Praemer A, Furner S, Rice DP. Musculoskeletal conditions in the United States (1st ed.). Chicago:

American Academy of Orthopedic Surgeons, 1992.

6 Shen T, Howe LH, Lumpkin JR. Osteoporosis in Illinois: Analysis of Hospital Discharge Records from 1992 to 1995. Springfield (IL): Illinois Department of Public Health, 1997 Dec.

7 Pennsylvania Health Care Cost Containment Council. PHC4 Issue Brief—Osteoporosis Facts and Figures [Internet]. Harrisburg: The Council, 1997 Nov 19 [accessed 2000 Mar 23]. Available from: http://www.phc4.org/reports/mcpr/00/Issue_Briefs/Osteoporosis/issuebrief2.htm.

8 Max W, Sinnot P, Kao C, et al. The burden of osteoporosis in California, 1998. Osteoporos Int 2002;13:493–500.

9 Kamel HK, Hussain MS, Tariq S, et al. Failure to diagnose and treat osteoporosis in elderly patients hospitalized with hip fracture. Am J Med 2000; 109:326–8.

10 Gehlbach SH, Bigelow C, Heimisdottir M, et al. Recognition of vertebral fracture in a clinical setting. Osteoporos Int 2000;11:577–82.

11 Melton LJ III, Thamer M, Ray NF, et al. Fractures attributable to osteoporosis: report from the National Osteoporosis Foundation. J Bone Miner Res 1997;12:16–23.

12 National Osteoporosis Foundation. America's Bone Health: The State of Osteoporosis and Low Bone Mass in Our Nation. Washington: The Foundation, 2002.

13 Tosteson AN, Jonsson B, Grima DT, et al. Challenges for model-based economic evaluations of postmenopausal osteoporosis interventions. Osteoporos Int 2001;12:849–57.

14 Campbell PR. Population Projections for States by Age, Sex, Race, and Hispanic Origin: 1995 to 2025. PPL-47. Washington: US Bureau of the Census, Population Division, 1996 Oct [accessed 2002 Apr 30]. http://www.census.gov/population/www/projections/ppl47.html.

15 National Center for Health Statistics. US Decennial Life Tables for 1989–91. Vol. II. State Life Tables No. 19, Florida. Hyattsville, (MD): The Center for Disease Control, 1998.

16 Keene GS, Parker MJ, Pryor GA. Mortality and morbidity after hip fractures. BMJ 1993;307: 1248–50.

17 Florida Hospital Inpatient Data File, 1998. Tallahassee (FL): State Center for Health Statistics, State of Florida Agency for Health Care Administration, 1998.

18 Melton LJ III, Lane AW, Cooper C, et al. Prevalence and incidence of vertebral deformities. Osteoporos Int 1993;3:113–9.

19 Melton LJ III, Chrischilles EA, Cooper C, et al. Perspective: how many women have osteoporosis? J Bone Miner Res 1992;7:1005–10.

20 Hip Fracture Outcomes in People Age Fifty and Over. OTA-BP-H-120. NTIS Order PB94-107653. Washington: United States Congress Office of Technology Assessment, 1994:1–95.

21 Osteoporosis: review of the evidence for prevention, diagnosis and treatment and cost-effectiveness analysis [introduction]. Osteoporos Int 1998;8:S7–80.

22 Cooper C, Campion G, Melton LJ III. Hip fractures in the elderly: a world-wide projection. Osteoporos Int 1992;2:285–9.

23 Clark AP, Schuttinga JA. Targeted estrogen/progesterone replacement therapy for osteoporosis: calculation of health care cost savings. Osteoporos Int 1992;2:195–200.

24 Jacobsen SJ, Cooper C, Gottlieb MS, et al. Hospitalization with vertebral fracture among the aged: a national population-based study, 1986–1989. Epidemiology 1992;3:515–8.

25 Stucki B. Can Aging Baby Boomers Avoid the Nursing Home? Washington: American Council of Life Insurers (ACLI), 2000 Apr.

26 MetLife Market Survey on Nursing Home and Home Care Costs. Westport (CT): Metlife Mature Market Institute, 2002 Apr.

27 Consumer Price Index, US. City Average, Medical Care Component. Washington: Bureau of Labor Statistics, US Department of Labor 2002.

28 Bohannon A, Hanlon J, Landerman R, et al. Association of race and other potential risk factors with nonvertebral fractures in community-dwelling elderly women. Am J Epidemiol 1999;149:1002–9.

29 Baron JA, Barrett J, Malenka D, et al. Racial differences in fracture risk. Epidemiology 1995;5:42–7.

30 Burge RT, Puleo E, Gehlbach S, et al. Inpatient hospital and post-acute care for vertebral fractures in women. Value Health 2002;5:301–11.

31 Bauer RL, Deyo RA. Low risk of vertebral fracture in Mexican American women. Arch Intern Med 1987;147:1437–9.

32 Ellis AA, Trent RB. Hospitalized fall injuries and race in California. Injury Prev 2001;7:316–20.

33 Gehlbach S, May S, Heimisdottir M, et al. Unrecognized costs of osteoporosis-related vertebral fracture [abstract F559]. J Bone Miner Res 1997;12(Suppl 1):S366.

34 Papaioannou A, Adachi J, Parkinson W, et al. Lengthy hospitalization associated with vertebral fractures despite control for comorbid conditions. Osteoporos Int 2001;12:870–4.

Appendix 1
Data Sources and Assumptions for Hip Fractures in Florida

Cost category	Source	Assumptions and comments
Inpatient		
Acute inpatient hospital	1998 FL AHCA Hospital Inpatient Data File*	Imposed high-cost outlier trim of $200,000. Reduced mean charges by 20% to reflect payer discounts and contractual adjustments. Included emergency department costs.
Acute inpatient physician services	1994 US OTA [20]	Reduced by 20% to reflect payer discounts.
Rehabilitation/ short-stay hospital	1998 NOF [21]	Assumed 12% of patients entered rehabilitation/short-stay hospital for average of 9 days within 1 year of event and mean cost $8561.
Readmit to acute inpatient hospital	1998 NOF [21]	Assumed 8% of patients readmitted to short-term acute hospital for average of 8 days within 1 year of event. Multiplied original hospital admission by 48.5% for age 50 to 64 years and 59% for age 65+ years.
Outpatient		
Home care	1998 NOF [21]	Assumed 30% probability of 6 months of care. Included cost of nursing services, rehab services, and DME at patient's home.
Nonmedical home care	1998 NOF [21]	Assumed 17% use by people with hip fractures. Included cost of social worker services, special transportation services, meal delivery, etc.
Posthospital/outpatient physician visits	1998 NOF [21]	Assumed eight visits after hospital discharge.
Other outpatient care	Ray et al. [1]	Outpatient hospital and "other" outpatient services (physical therapy, diagnostic radiology, medications, orthopedic and other supplies). Multiplied mean inpatient care costs by 1.8% (proportion of other outpatient to inpatient care costs).
LTC		
LTC facility	1998 NOF [21] and 1998 FL AHCA	Multiplied discharge rates to Florida LTCF, by age group, by length of stay in LTC facility and cost per day based on annual cost of $45,260. *Discharge rate (%) to LTCF for < 1-year or = 1-year stay:*

Discharge rate (%) to LTCF, by length of stay

	Women		Men	
Age (years)	<1 year	=1 year	<1 year	=1 year
50–64	21.0	10.5	20.4	10.2
65–74	34.7	17.4	33.7	16.4
75–84	41.6	20.8	38.6	19.3
85+	45.6	22.8	43.1	21.5

Cost category	Source	Assumptions and comments
Disability, long-term	1998 NOF [21]	Assumed 27% of people with hip fracture incurred disability costs such as DME and additional 28% had moderate disability costs (rehabilitation, nurses, nurses aides, social workers, home aides, special transportation, and meal delivery).

*Updated to year 2000 with medical component of the Consumer Price Index (US Bureau of Labor Statistics).
Abbreviations: AHCA, Technology agency for Health Care Administration; DME, durable medical equipment; LTC, long-term care; NOF, National Osteoporosis Foundation; OTA, Office of Technology Assessment.